METHODS REFERENCE — STANDARD OPERATING PROCEDURE

Measurement of visceral adipose tissue by low-dose CT at L3: acquisition, slice localisation, segmentation, bowel-artefact correction, and height/waist normalisation

A reproducible method for single-slice VAT quantification and VATI calculation, for reference by audits and clinical reports.

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Summary

This document specifies how Virtual Cath Lab Surrey (VCL-Surrey) Ltd measures visceral adipose tissue (VAT) from low-dose CT, so that the method can be reproduced and cited. Height is measured with a stadiometer and waist circumference by the WHO protocol; both feed the waist-to-height ratio used to select patients for imaging. A single axial slice is acquired 3 cm above the lower margin of L3, localised on the mid-sagittal scout. Adipose tissue is segmented on TeraRecon Aquarius iNtuition using a fixed Hounsfield window of −150 to −50 HU, with the peritoneal cavity outlined to separate visceral from subcutaneous fat. Faecal bowel content that falls within the fat window is removed using a purpose-built correction tool (developed with AI assistance) that can only reduce, never inflate, the measured VAT. VAT area is normalised to height squared to give the visceral adipose tissue index (VATI, cm²/m²), interpreted against sex- and ethnicity-specific reference ranges.

1. Anthropometry

1.1 Height

Standing height is measured in all patients with a wall-mounted stadiometer, shoes removed, heels together, head in the Frankfort horizontal plane, recorded to the nearest 0.1 cm. Height squared (m²) is used to index VAT (see §7).

1.2 Waist circumference and waist-to-height ratio

Waist circumference is measured WHO-style[1] — at the midpoint between the lowest rib and the iliac crest, in a horizontal plane, at the end of normal expiration, with a non-elastic tape held snug but not compressing the skin. Patients are guided through a standardised self-measurement where appropriate using the service's illustrated protocol ("How to measure your waist at home").[2] The waist-to-height ratio (waist ÷ height, same units) is calculated; a ratio above 0.5 is the threshold used to offer VAT CT, a cut-point that predicts cardiometabolic risk better than BMI or waist circumference alone[3,4].

2. CT acquisition

A low-dose, non-contrast axial CT is acquired with the patient supine, arms raised, using a standardised breath-hold instruction and ALARA dose principles. Tube parameters, reconstruction kernel and slice thickness are held constant within and between patients so that serial scans are directly comparable; low-dose iterative reconstruction is appropriate for body-composition work and does not degrade VAT quantification.[5] In this service the acquisition uses 120 kVp, 200 mA and a 1 mm slice at a fixed CTDIvol of approximately 19.1 mGy, giving a median additional effective dose of about 0.13 mSv. Because only a single thin slice is taken, the added dose is essentially independent of body size — it does not scale with BMI or waist circumference — and tube output is increased only for the largest patients.

Field of view: the reconstructed field of view must encompass the entire body contour at the measurement level, so that the full subcutaneous fat envelope is captured without truncation at the skin margin. Truncation of subcutaneous fat invalidates both the subcutaneous-area measurement and the visceral-to-total fat ratio; the FOV is therefore set to the patient's body habitus rather than a fixed small FOV. In practice the reconstructed field of view is typically 400–500 mm, enlarged further for a large body habitus.

3. Slice localisation

A single axial slice is measured **3 cm above the lower margin (inferior endplate) of the L3 vertebral body**, identified on the mid-sagittal scout. This skeletal landmark is fixed by vertebral anatomy and is therefore independent of respiration, abdominal-wall laxity and inter-scan positioning drift. It has the strongest reported association with total VAT volume and cardiometabolic risk[6] and the lowest coefficient of variation for serial change of the single-slice levels studied.[7] The level itself is unchanged from earlier practice; only the method of locating it has been standardised, as set out below.

> **Localisation method (SOP Addendum 1)**
>
> **Primary — sagittal-scout offset:** display the lateral scout or a true mid-sagittal reconstruction; identify the L3 inferior endplate (confirm by counting up from L5–S1: L5→L4→L3, noting any transitional anatomy); place the reference line on the L3 inferior endplate and move the prescribed axial slice 30 mm cranially along the table/z-axis (not along the curve of the spine); acquire at this level.
>
> **Fallback — slice-count check:** with a fixed, recorded reconstruction interval, count up from the L3 lower-endplate slice — 30 mm corresponds to 6 slices at 5 mm, 10 at 3 mm, 12 at 2.5 mm, or 15 at 2 mm.
>
> **Sanity check & serial scans:** 30 mm above the L3 lower margin sits near the L2–L3 disc / superior endplate of L3 (an L3 body is ~3 cm tall); if the slice lands at mid-body or lower, re-check the offset. For follow-up, the previous prescription is replicated and a scout screenshot saved into the study.

4. Adipose-tissue segmentation

Image analysis is performed on **Aquarius iNtuition (TeraRecon, Durham, NC, USA)**. Pixels are classified as adipose tissue when their attenuation falls within a fixed Hounsfield window of **−150 to −50 HU** (adipose tissue spans roughly −300 to −10 HU; the narrower −150 to −50 HU window is used operationally and held constant across all studies for inter-patient and longitudinal reproducibility). The peritoneal cavity is manually outlined: adipose pixels inside the outline are classified as visceral adipose tissue (VAT, intraperitoneal) and those outside as subcutaneous adipose tissue (SAT, extraperitoneal). The workstation reports the cross-sectional area of each compartment in cm².

5. Bowel-artefact correction

Faecal bowel content is a heterogeneous mixture of soft tissue, fluid and gas and frequently contains pixels whose attenuation falls within the adipose window (typically −60 to −100 HU). Where bowel loops lie within the peritoneal outline — most often the right colon and rectum — these pixels are mis-classified as VAT and inflate the reported area. This is a recognised source of error: failure to exclude intracolonic content overestimates visceral fat area by about 10 cm² on average (up to ~19% of VAT area, occasionally more).[8] Correcting it materially improves accuracy of both VAT and the visceral-to-total fat ratio.

To correct this systematically, VCL-Surrey uses a purpose-built tool developed with AI assistance (Claude, Anthropic). The tool:

- detects connected regions of VAT-classified pixels inside the peritoneal outline that are spatially adjacent to intraluminal gas (HU < −200), characteristic of bowel;
- presents the candidate regions to the operator as a review mask, which the operator can extend, retract or override with a brush tool;
- subtracts only pixels originally classified as VAT — so a correction can only reduce, never inflate, the VAT area;
- recalculates the corrected VAT area and the visceral/(visceral + subcutaneous) ratio, retaining the original workstation output alongside the corrected value, with a full audit trail of the changes made.

Subcutaneous fat is unchanged by the correction. The original and corrected VAT values are both stored so that the effect of correction is auditable at cohort level.

6. Height normalisation — VATI

To account for body size, VAT area is normalised to height: **VATI = VAT area (cm²) ÷ height² (m²)**, directly analogous to BMI, allowing comparison across patients of differing stature.

7. Interpretation

Both raw VAT area and VATI are interpreted against published sex- and ethnicity-specific reference ranges. For Caucasian adults, elevated metabolic risk begins at VATI ≥ 38.7 cm²/m² (men) and ≥ 24.9 cm²/m² (women).[9] The full sex- and ethnicity-specific target ranges applied by the service, and their derivation, are set out in the companion reference-range document.[10] East and South Asian populations reach equivalent risk at lower VATI than Caucasians, so a single set of cut-points must not be applied to a multi-ethnic cohort.

8. Quality control

- Fixed HU window (−150 to −50 HU) and fixed skeletal landmark (3 cm above the L3 lower margin) applied to every study.
- Identical acquisition and reconstruction parameters within and between serial scans; previous prescription replicated for follow-up.
- Bowel correction can only reduce VAT; original and corrected values retained for audit.
- Intra- and inter-observer variability should remain < 5%.

Declarations

Authorship and conflict of interest: this methods reference was prepared by Dr E Leatham and Dr M Hickman, directors of Virtual Cath Lab Surrey (VCL-Surrey) Ltd, a commercial provider of CT imaging services. The bowel-artefact correction described is implemented in a commercial software tool (the MedicalSpace VAT Analysis Suite), and the cited patient-education resource is hosted on vat-trap.com; both are owned and operated by MedicalSpace Ltd, in which the authors have an interest. The method is published openly to support reproducibility and external scrutiny; interpretation thresholds are drawn from the peer-reviewed literature rather than any in-house standard. No external funding was received.

Disclaimer: vat-trap.com is owned and operated by MedicalSpace Ltd and provides general educational information only. It is not a medical service, and its content does not constitute medical advice or replace individual clinical assessment by a qualified professional.

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